Handling and Storage of APPLES *in Pallet Boxes*

AN INTERIM REPORT

Agricultural Marketing Service
and
Agricultural Research Service

U.S. DEPARTMENT OF AGRICULTURE

AMS-236

PREFACE

This report is based on research directed cooperatively by the Agricultural Marketing Service and the Agricultural Research Service. The Agricultural Marketing Service research was conducted by the Fruit Industries Research Foundation, Inc., under a contract with the United States Department of Agriculture.

The results reported are preliminary and the report itself should be considered to be an interim report. Because of the great interest in the results of this research by growers, storage and packinghouse operators, suppliers, and the apple industry generally, it was decided to release this report prior to completion of the research project. The intent is to make the preliminary results available so apple people can take advantage of the research to date. It is anticipated that in the Pacific Northwest alone the apple industry will be spending in excess of $1,250,000 for pallet boxes and associated equipment during the 1958-59 season. This report should furnish guidance for these expenditures, and help expand the market for farm products.

Acknowledgment is made to Harold A. Schomer, Biological Sciences Branch, and G. F. Sainsbury, formerly of the Transportation and Facilities Branch, Marketing Research Division, Agricultural Marketing Service, for their guidance and helpful suggestions in conducting the bruising and cooling rate studies.

Acknowledgment is made of the cooperation and assistance given by individuals and organizations in the apple industry in making this research possible.

Agriculture-Washington April 1958

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SUMMARY

The apple industry in all areas of the United States, especially the Pacific Northwest, has shown increased interest in the use of pallet boxes for the handling and storage of apples. Although not a new idea, pallet boxes recently were adopted for apples because of the savings which can be realized and because there have been technological developments occurring in the industry that made their adoption feasible. An especially important contributing factor to the adoption of pallet boxes in the Pacific Northwest is the shift away from standard wood boxes for shipping to a fiberboard shipping container. This shift has necessitated the purchase of field containers of one kind or another and in many instances the pallet box has been the one selected.

Using pallet boxes requires some use of special equipment at the orchard. However, at a storage and packinghouse already using pallets, the expenditures may be small. For example, the same industrial forklift truck used for handling pallet loads of standard boxes can be used for handling the pallet boxes. The straddle trailer or straddle truck have found good application in transporting the pallet boxes from the orchard to the storage and packinghouse.

A variety of pallet boxes were studied. These boxes included variation in design, materials, and dimensions. In conducting this study the cooling rates were evaluated, the bruising characteristics were observed, structural features were considered, and labor and equipment costs were determined.

The cooling tests indicated that generally apples stored in pallet boxes cooled as well or better than those stored in standard boxes on pallets. Some pallet boxes, where the free space of the sides or bottom ranged from 8 to 11 percent, performed better than standard boxes on pallets. Side spacing gave results comparable with bottom spacing.

Apples in pallet boxes had fewer bruises than apples in field boxes. Tests indicated that pallet boxes equipped with corrugated fiberboard liners bruised fewer apples than those not so equipped. If liners are not used, diagonally cut corner posts, eased edges of all inner surfaces of the boards, bullnosed edges, and smooth box interior surfaces tended to reduce bruising.

Records of 24,200 boxes used commercially in Washington during the 1957-58 season indicated that fewer than 1 percent of the boxes were damaged beyond repair and over 70 percent of those so damaged were the result of accidents; 2.7 percent incurred repairable damage, most of which was minor; and 7 percent of those employing corrugated fiberboard liners showed liner damage, practically all of which was caused by water.

Comparative costs of using pallet boxes and standard boxes handled on pallets show a distinct advantage for the pallet box. A grower-packinghouse operator should be able to save $70 to $85 per 1,000 standard box equivalents by shifting from a palletized standard box operation to one using pallet boxes. On a volume of 100,000 equivalent standard boxes, an annual saving of between $7,000 and $8,500 might be expected.

One of the more important considerations is the amount of refrigerated space which can be saved by switching to the use of pallet boxes. Depending on the dimensions of pallet box used, about 20 percent more fruit can be stored in the same storage space when compared with standard boxes handled on pallets.

Although commercial operators were generally satisfied with the pallet boxes they were using and have realized savings and improved handling, there are some shortcomings of these boxes which should be given attention. They should be made stronger to resist skewing and other damage. They should have bottoms which do not spring up during handling. They should have better fork entry spaces to facilitate pick up and positioning depending on floor surface. They should have more desirable liners if they are used. They should be designed for easier handling.

Some compromises must be made in the structural features of pallet boxes. However, consideration should constantly be given to improvement of those features which influence bruising, cooling, durability, economy, handling, and dimensions.

HANDLING AND STORAGE OF APPLES IN PALLET BOXES

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INTRODUCTION

Apple producers and storage and packinghouse operators have shown great interest in pallet boxes in the past 2 years.

Pallet boxes are not an innovation for the handling and storage of agricultural products. In 1944, studies were made in Colorado on their use in connection with potatoes. One of the largest early users of pallet boxes is located in Clear Lake, Iowa. This operator's entire crop of potatoes and onions are conditioned, stored, and handled in pallet boxes. Results of studies made there indicate that pallet boxes can reduce labor requirements and investment in facilities, and maintain the quality of the product. The pallet box method of handling is rapidly spreading into use in packing and storage houses for other agricultural products.

During the 1952 harvest season personnel of Agricultural Research Service and Michigan State University cooperated with a Michigan grower in constructing six bulk boxes with end gates for handling McIntosh apples for the fresh fruit market. This work was expanded and during the 1955 season approximately 10,000 bulk boxes were used to handle about 300,000 bushels of Michigan apples. Results of this work were published early in 1956. 2/ During the 1955-56 season, USDA research on bulk harvesting of apples in pallet boxes in the Pacific Northwest began at the Tree Fruit Experiment Station, Wenatchee, Wash., in cooperation with the Washington Agricultural Experiment Station. This research was designed to determine the effect of depth of fruit in a large container on bruising or marking of the fruit.

The 1956-57 season saw wider commercial adoption of pallet boxes in Michigan. A grower in Washington also used pallet boxes for a small amount of his crop during that season.

This season, 1957-58, there has been greater use of pallet boxes for harvesting, handling, and the storage of apples in Michigan and Washington.

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2/ Gaston, H. P. and Levin, J. H. Handling Apples in Bulk Boxes. Mich. State Univ. Spec. Bul. 409, April 1956.

In Michigan it is estimated that 25 percent of the 1957-58 apple crop was handled in pallet boxes. In the Pacific Northwest, 9 operators have put about 25,000 pallet boxes into use for harvesting of about 900,000 standard boxes of fruit. In many major producing areas growers and packinghouse operators have also installed pallet boxes.

Purpose of the Research

Traditionally, the Pacific Northwest to a large extent has used the same standard wood box in which apples are shipped as a picking and storage container. Continued increases in the costs of this box, the use of new merchandising methods, and the adoption of improved technology for packing certain types of fiberboard containers have brought a marked shift away from wood boxes for shipping apples to market. This means that many plants are faced with heavy expenditures for picking and storage containers. They could use field boxes of the same size, standard boxes, or some other size containers. It has been shown in other areas that a larger container is less expensive to use than the standard wood field box and this research on pallet boxes was undertaken to determine if the larger container is better. If the pallet box is better, it is necessary to determine the best size, design, and construction materials.

Many of the pallet boxes already built and in use for handling apples have been built without complete thought given to construction features. As a result, many will not perform most satisfactorily nor result in the lowest cost to the users.

Research done to date, by both the Agricultural Research Service and the Agricultural Marketing Service, is included in this report. The efforts in connection with this study are to give the apple industry of the Pacific Northwest the design criteria and the methods of using the pallet box which will give the lowest cost consistent with good storage practice and maintenance of fruit quality.

EQUIPMENT AND METHODS

Pallet boxes call for equipment changes in the orchard and at the warehouse. All commercial pallet boxes and most of the experimental ones studied weigh approximately 1,000 pounds when filled with fruit. Power lift equipment is necessary for handling them. Most pallet boxes weigh from 110 to 140 pounds empty and when handled manually require 2 men to handle except when dragged a few feet.

In orchards forklift equipment, available as attachments for tractors, is necessary to handle pallet boxes. In most cases this equipment is new to the grower. Transportation equipment already in use is well suited to hauling pallet boxes. At the warehouse, forklift trucks handle pallet boxes in the same manner as loads of standard apple boxes on pallets. Except for dumping devices, the major equipment changes necessitated in shifting to pallet-box handling are in the orchard.

Distributing Pallet Boxes in the Orchard

Empty pallet boxes can be distributed in the orchard from tractor-drawn stoneboats, orchard trailers, and tractor-mounted forklift attachments. One man can drag boxes from the low surface of the stoneboat (figs. 1 and 2). A 2-man crew speeds up the operation and may be desirable, particularly if an orchard trailer is used. Pallet boxes must be carefully positioned by the trees so that they can be readily picked up with a tractor forklift. This is particularly true if the boxes have only two-way entry pallets and the trees are closely spaced. A stoneboat with 6 or 8 pallet boxes loaded one high can be maneuvered in the orchard with a minimum amount of injury to the trees and unpicked fruit.

Empty pallet boxes can be distributed in the orchard with the tractor forklift that is used to haul out filled boxes (fig. 3). The operator takes along two empty boxes into the orchard when he goes to pick up filled boxes. This may be a more efficient operation in some cases, as the tractor carries a load both ways. It has worked out satisfactorily for some producers. There is apt to be damage to unpicked fruit when boxes are moved two high into unpicked trees. Extra tractor travel is sometimes necessary with this method as empty boxes have to be located ahead of where the filled boxes are picked up.

When empty pallet boxes are hauled two high, some means is necessary to hold the top box in place. A hydraulically-controlled hold-down of the type used for steadying standard boxes on pallets, such as shown in figure 4, can be used. It is, however, a considerable added expense and tends to catch limbs when moving around the orchard. Simple flange-like brackets, one on either side of the bins and fastened to the vertical back frame of the tractor forklift, are much simpler and cheaper. They do not require operating time nor catch limbs (fig. 3).

Filling Pallet Boxes

Pallet boxes are filled much the same as standard boxes. Pickers usually empty their picking bags into the pallet boxes from different sides. They dump into the low side or spot to prevent unnecessary rolling of the apples. Careless emptying of picking bags without lowering them to the bottom of the pallet box, results in excessive bruising. Piece-work rates by the pallet box were found desirable in order to have a check on individual pickers.

Usually pickers liked pallet boxes better than standard boxes after they became used to them. Setting up of field boxes and much leveling off of filled boxes is eliminated with pallet boxes and harvesting goes somewhat faster. Emptying into pallet boxes is easier. Pickers can lean against the edge of the pallet box and avoid much of the back strain that results when they empty into standard field boxes.

NEG. BN-5575

Figure 1.--Stoneboat used to distribute pallet boxes in the orchard.

NEG. BN-5576

Figure 2.--Distributing empty pallet boxes in the orchard with a tractor-drawn stoneboat.

NEG. BN-5577

Figure 3.--Tractor with rear mounted forklift unit used for distributing empty pallet boxes and hauling full pallet boxes in the orchard. A pair of brackets steadies the boxes during transportation.

NEG. BN-5578

Figure 4.--Tractor with rear mounted forklift unit equipped with hydraulically-operated hold-down or load stabilizer. This hold-down rests on the top of the pallet boxes and steadies them during transport.

Transportation Within Orchard

It was necessary to move partially-filled pallet boxes ahead when trees were finished to save steps for the pickers. Forklift equipment was used to do this and with larger picking crews one tractor forklift sometimes was necessary just for this operation. The same forklift unit usually was used to distribute empty pallet boxes ahead of pickers and move filled boxes to the edge of the orchard. Where a forklift unit is used just for this purpose, it can be an inexpensive, low-lift 1,000-pound capacity, fork attachment which mounts on the 3-point hitch of many tractors with built-in hydraulic lifts (fig. 5). Such units lift pallet boxes high enough for moving around the orchard and are available for less than $200. For smaller picking crews, the tractor forklift used for moving filled pallet boxes from the orchard also was used to move partially-filled boxes ahead for the pickers.

Usually tractor forklift equipment with about a 5-foot lift and 2,000-pound capacity is necessary to move filled pallet boxes from the orchard. The higher lift is necessary to set one pallet box on another and to set boxes two-high on a highway truck. Two 27-box capacity pallet boxes weigh about 1 ton gross when filled. Forklift attachments are available for several types or combinations of mounting for nearly all orchard tractors. Such equipment is shown in figures 3, 4, 5, and 6. The simplest, least expensive type of such a lift is shown in figures 3, 4, and 5. It mounts on the rear of the tractor with a counter-balancing weight on the front and uses the tractor hydraulic system for power to lift and tilt the fork. In addition, the unit in figure 4 has a hydraulically-operated hold-down or load stabilizer such as that used for transporting boxes on pallets.

The base price of such a forklift attachment is from $800 to $900. A hydraulic-powered side shift for the fork is desirable to assist in loading pallet boxes on a truck, but it adds around $200 to the cost of the unit.

Some operators prefer the truck-loading forklift on the front of the tractor. With such an arrangement, a low-lift, inexpensive fork attachment can also be mounted on the rear of the tractor. Thus 4 empty boxes per load can be hauled into the orchard (fig. 6). However, such a combination is not satisfactory for filled boxes when the soil is wet or soft as the front wheels cut too deeply into the soil. Also, such a combination adds considerable load on the front tires and wheel bearings of the tractor making oversize front tractor tires and power steering desirable. Some manufacturers provide a special front tractor axle for such an attachment. When trees are closely spaced it is often necessary to move filled boxes one high to open spaces or roadways before decking two high.

One orchardist made a convenient conversion of the loader attachment for his tractor for handling pallet boxes by replacing the scoop with forks for lifting and loading the boxes (fig. 7). Machinery manufacturers of truck rakes, hay loaders, and other similar equipment offer forklift attachments as standard equipment. Crawler-mounted tractors with standard forklift attachments were also used for handling pallet boxes.

NEG. BN-5579

Figure 5.--Three-point tractor hitch for moving and transporting pallet boxes in the orchard.

NEG. BN-5580

Figure 6.--Tractor with a high-lift fork attachment in the front and low-lift fork in the rea. The high-lift attachment is used to tier pallet boxes two high and the rear low-lift is used for hauling, thereby doubling the payload.

NEG. BN-5791

Figure 7.--Tractor equipped with forklift converted loader attachment used to load pallet boxes onto a flat-bed orchard trailer.

Loading and Transportation

Pallet boxes are transported with equipment already standard to the industry. Motor trucks, commonly used for standard boxes, were also used for pallet boxes. A forklift unit is necessary for loading pallet boxes on such a truck. A typical operation is shown in figure 8. Here a 16-pallet box load equivalent to about 432 loose standard boxes is being completed. For shorter hauls, regular, flat-bed orchard trailers were successfully used, usually with boxes loaded only one high (fig. 9).

Pallet boxes are also well suited for straddle-carrier hauling, and the straddle units, either truck or trailer, can be used without modification for either pallet boxes or standard boxes on pallets. The loads can be set up at the edge of the orchard as the filled boxes are brought out (fig. 10). With this system the tractor forklift need not be on hand for loading and one box handling is eliminated. The straddle carrier drives over the load of boxes on the loading skids and picks it up as shown in figure 11 in a matter of seconds. Usual straddle-carrier loads are 12 or 14 boxes. Adapted lumber carriers of smaller capacity are also being used.

One operator transported filled pallet boxes two high on a rear-mounted tractor forklift directly from the orchard to his packing plant. Empty pallet

NEG. BN-5792

Figure 8.--Motor truck being loaded with full pallet boxes by use of tractor equipped with high-lift fork attachment.

NEG. BN-5793

Figure 9.--Tractor and orchard trailer backed into a loading pit so that another tractor equipped with a rear low-lift fork attachment can load the trailer. Note counter weight on front of tractor.

NEG. BN-5794

Figure 10.--Setting up at the edge of the orchard a load of 14 pallet boxes on a bolster for pick up by straddle-carrier. Note empty bolster on the left.

NEG. BN-5795

Figure 11.--Straddle truck picking up a load of 14 full pallet boxes from bolster at the edge of an orchard.

boxes were hauled on the return trip to the orchard. The distance from the packing plant to the orchard was very short.

At Storage and Packinghouse

Unloading and handling pallet boxes at storage was done with the same equipment used for handling unit loads on pallets (fig. 12). Although operating methods are a little different, filled pallet boxes were found to be more stable than individual boxes on pallets so tying was unnecessary to assure stability of the load. In fact, the stability of the stacks was greater in storage though the stacking operation was found to be a little more time consuming. Some boxes went into cold storage and others direct to the packing line, depending upon the plant operations and capacities. Two Yakima plants used their 6,000 pallet boxes an average of about one and a half times during the 1957 season.

There was evidence that the smaller, 1-ton, industrial forklift truck was somewhat inadequate apparently because 2 pallet boxes were a slightly larger load than these lift trucks were capable of handling. The use of pallet boxes may call for heavier lift-truck equipment to handle greater loads with ease. The exact placement necessary occasionally required the lift-truck operator to back up and come in to place his load two or three times. This would suggest that use of side-shift equipment on lift trucks in the pallet-box operation would be desirable.

NEG. BN-5796

Figure 12.--Unloading pallet boxes of apples from a motortruck at the storage plant with an industrial forklift truck.

The major, new equipment necessary at the packing plant is for emptying pallet boxes. This past season nearly all of the commercial operators using pallet boxes installed dumpers of the box-inversion type. Figures 13 and 14 show typical installations. This type of dumper has a capacity of over 400 bushels per hour and provides a fairly continuous flow of fruit to the packing line. Pallet boxes are fed to the unit on a conveyor, are slowly inverted in a box-inversion section where the boxes are held between two conveyor belts, and are slowly lifted away from the apples as the fruit is spread into an even layer on a conveyor belt and fed into the packing line. This type of dumper costs from $4,000 to $6,000, including installation. Savings possible by pallet-box harvesting justify the expense.

Handling empty pallet boxes required no new equipment. At the end of the dumper, conveyor equipment carried the empty boxes to a position where lift trucks could pick them up. These conveyors were part of the dumper installation.

Equipment for the Smaller Grower and Plant Operator

Pallet box harvesting as described necessitates investment in new equipment for most growers and plants which creates an economic problem for the smaller grower and plant operator. Most smaller growers already have an orchard tractor, usually on the 3-point hitch type, and an orchard trailer. Such as operator can manage with the addition of a low-cost, low-lift fork attachment mounted on the rear of his tractor. Pallet boxes can be loaded one high on the trailer using a pit or hillside loading site, and hauled to the plant where forklift unloading equipment is available.

Some smaller plants, particularly grower-packer plants, may desire to convert to pallet-box harvesting, but are held back by the large investment necessary for pallet box dumping equipment. Two possible methods or types of pallet box-emptying equipment have been used satisfactorily which involve less costly equipment.

One such pallet-box dumper in a Yakima plant is shown in figures 15 and 16; 3/ this dumper is similar to equipment developed and used in the Midwest. It provides interrupted rather than continuous flow of fruit, but the flow can be evened out more or less by accumulating some fruit ahead of the grading table. Also two units may be used side by side to effect a continuous flow of fruit.

With this type of box dumper, the pallet box is rolled into place under a top cover with an emptying door in one side. A reversing, gear-reduction, electric motor with a pivoting forklift brings the box into emptying position at the start of the packing line. The emptying door is opened allowing the apples to flow onto the conveyor (fig. 16).

3/ Levin, J. H. and Gaston, H. P. A Bulk Box Dumper for Handling Fruit. Mich. Agr. Expt. Sta. Quarterly, May 1957.

NEG. BN-5797

Figure 13.--Device or dumper, box inverting type, used for emptying pallet boxes.

NEG. BN-5798

Figure 14.--View of the discharge end of an inverting type, pallet box dumper.

NEG. BN-5799

Figure 15.--A low-cost pallet box dumper.

NEG. BN-5800

Figure 16.--Dischrage side of a low-cost pallet box dumper. The flow of apples to the packing line is regulated by a hand-controlled trap door in the dumper cover.

On the unit shown the average time for emptying a 27-box pallet box was approximately 7 minutes of which 1-3/4 minutes was spent changing boxes. With a more convenient, efficient installation, the percentage of time required for changing would be less. The rate of operation, which was about 215 loose-filled boxes per hour, depends on the size and speed of the grading crew. As the rate increases, the percentage of time required for changing boxes increases. With the operation shown, there was an accumulation of apples in the old-style washer used in the packing line just ahead of the grading crew. This permitted evening out the flow to the grading crew so that they received almost a continuous flow of fruit.

A pallet-box dumper of the type shown in figures 15 and 16 costs around $500. This unit was satisfactory and saved the plant operators considerable investment over the larger capacity box dumpers. Their planned operations will require handling from 500 to 1,000 pallet boxes per season.

The other system using lower-cost pallet-box emptying equipment necessitates the use of an emptying door or end gate in one side of the box. Such an addition to the box costs an estimated one dollar per box and, with large-scale operations, might equal the cost of a dumper. Pallet boxes wit the trap door are rolled or lifted into place and tipped to a maximum of about 30 degrees with a suitable mechanism. Opening the door allowed the apples to flow out onto the conveyor at the start of the packing line.

No comparative fruit injury studies were made in Washington in 1957 between the box-inverting and the trap-door types of dumpers. Tests were made in British Columbia with both types of emptying and the results with each were reported to be comparable as far as fruit marking or other injury was concerned.

TYPES OF PALLET BOXES STUDIED

In conducting the research, it was necessary to limit the number of different types of pallet boxes to be considered. Eleven types were studied in all but the cooling studies. Four were constructed by the Agricultural Research Service, 3 were already in commercial use, and 4 were constructed by the Agricultural Marketing Service for plant handling, cooling, and storage. Dimensions and structural features of the 11 pallet boxes studied are shown in table 1.

The 4 ARS pallet boxes are actually 2 types--one uses plywood sides, the other tightly spaced individual boards. All ARS pallet boxes have spaced bottoms. Outside heights are 30 and 32 inches. All 4 are mounted on 4-way pallets.

The 3 commercial pallet boxes for which data were developed included one lined with fiberboard, the second had solid sides and solid bottoms with 1½-inch slot around the bottom, and the third had spaced sides and bottom.

Table 1.--Dimensions and structural features of 11 pallet boxes studied

Name	Characteristics	Corner	Special feature	Pallet type	Outside dimensions			Inside dimensions			Net volume	Net capacity based on			Weight of apples	Weight of bin
					Length	Width	Height	Length	Width	Depth		Weight: cu.ft.	Weight: of 42#	Weight: of 35#		
					Inches	Inches	Inches	Inches	Inches	Inches	Cu.ft.	Bushel	Bushel	Field boxes	Pounds	Pounds
AMS-1	Solid sides, spaced bottom	diagonal 1/	Removable $9\frac{1}{2}$" high end section	2-way	47	47	39-7/8	$45\frac{1}{2}$	$45\frac{1}{2}$	34-7/8	41.0	32.8	32.3	38.8	1,357	144
AMS-2	Spaced sides, solid bottom	1 x 4		2-way	40	36	30	$38\frac{1}{2}$	$34\frac{1}{2}$	25	19.1	15.3	14.7	17.7	619	95
AMS-3	Solid sides, spaced bottom	diagonal	No pallet	none	47	40	$30\frac{1}{4}$	$45\frac{1}{2}$	$38\frac{1}{2}$	$29\frac{1}{2}$	28.4	22.7	21.9	26.3	920	111
AMS-4	Spaced sides and bottom	1 x 4	Removable side	4-way	47	47	29	43	40	25	24.4	19.5	18.8	22.6	791	126
ARS-1	Solid sides, spaced bottom 2/	diagonal 1/		4-way	47	40	30	$45\frac{1}{2}$	$38\frac{1}{2}$	$24\frac{1}{4}$	23.8	19.0	18.4	22.0	771	123
ARS-2	Plywood sides, spaced bottom 2/	diagonal 1/	Plywood	4-way	47	40	32	$45\frac{1}{2}$	$38\frac{1}{2}$	$26\frac{1}{4}$	25.9	20.7	20.0	24.0	839	109
ARS-3	Plywood sides, spaced bottom 2/	diagonal 1/	Plywood	4-way	47	47	30	$45\frac{1}{2}$	$45\frac{1}{2}$	$24\frac{1}{4}$	28.3	22.6	21.8	26.2	917	135
ARS-4	Solid sides, spaced bottom 2/	diagonal 1/		4-way	47	47	32	$45\frac{1}{2}$	$45\frac{1}{2}$	$26\frac{1}{4}$	30.7	24.5	23.7	28.4	995	146
Comm.-1	Wide spaced side and bottom	diagonal	Fiberboard lined	2-way	48	$47\frac{1}{2}$	36	$46\frac{1}{2}$	46	32	39.2	31.4	30.9	37.1	1,298	150
Comm.-2	Solid sides and bottom	1 x 4	$1\frac{1}{2}$" slot around bottom	2-way	48	48	29	$46\frac{1}{2}$	$46\frac{1}{2}$	24	29.6	23.7	22.8	27.4	959	136
Comm.-5	Spaced sides and bottom	2 x 4	Edges not rounded	2-way	48	48	29	$46\frac{1}{2}$	$46\frac{1}{2}$	24	29.6	23.7	22.8	27.4	959	132

1/ 4" x 4" cut diagonally, not of 3.4" x 3.4".
2/ Fourteen design variations of the four sizes were used.

The AMS boxes were especially constructed to test certain variations in design which were not available with the ARS and commercial pallet boxes. AMS-1 had removable gates to permit easy filling, solid sides, and a spaced bottom. This box, with an overall height of 40 inches, was constructed to test the effect of deeper boxes on fruit bruising. AMS-2 was built on a smaller pallet base to provide comparison with operations using standard apple boxes on 36- by 40-inch pallets. AMS-3 was designed without stringers underneath and was intended to be handled with a clamp-type industrial lift truck. AMS-4 was designed with removable sides and inside dimensions of such size that it could be used either for storing apples in bulk or for storing packed fiberboard shipping containers of apples.

COOLING STUDIES

Earlier studies on the storage life of apples indicate that the sooner field heat can be removed from apples, the longer the fruit will keep in storage. With this in mind, it was determined that studies should be made of the rate that apples cooled in the different types of pallet boxes. These results were compared with the cooling rates of fruit held loose in field or standard boxes stacked on pallets. The types of pallet boxes were so selected that as many variables as possible were studied to determine their effect on the cooling of fruit.

The cooling studies were essentially an investigation of the effects of box dimensions and ventilation on cooling performance.

The cooling characteristics of 9 different types of pallet boxes containing unpacked apples were studied in tests conducted in 2 commercial apple storage plants in the vicinity of Yakima, Wash. At each test location the cooling performance of pallet loads of standard apple boxes filled with unpacked fruit served as a check to adjust for the differences between the two storages.

The characteristics of the various boxes studied are shown in table 2. In all pallet boxes, except AMS-3, air could pass above and below each box, so the minimum dimension from center to exposed face of the body of fruit is one-half the depth. For 6 of the pallet boxes, this distance (D/2) ranges from 12 to 12½ inches. For the 35-inch deep box with solid sides and spaced bottom, D/2 equals 17½ inches and for the 32-inch deep box with fiberboard liner it is 16 inches. For the box without a pallet, the minimum center to side face distance is 20 inches. Pallet box, Comm.-2M, is the same type of box as Comm.-2 but the interior was completely lined with paper to give the effect of solid sides and solid bottom with no vent at all. Only the top of the box was open to permit entrance of air.

Both convection and conduction play a part in the cooling of fruit in these containers; however, the relative importance of each in the total performance is unknown. Cooling accomplished by conduction is influenced by a number of variables. The most important, in these tests, was the distance

Table 2.--Dimensions and specifications of boxes used in cooling performance tests

Name	Characteristics and remarks 1/	Outside dimensions			Inside depth	Free area in	
		Width	Length	Height		Bottom	Sides
		Inches	Inches	Inches	Inches	Percent	Percent
AMS-1	Solid sides, spaced bottom with removable $9\frac{1}{2}$" high sections on both ends 2/	47	47	39-7/8	34-7/8	9.5	0
AMS-2	Spaced sides, solid bottom	40	36	30	25	0	11.3
AMS-3	Solid sides, spaced bottom without pallet	40	47	30-1/4	29-1/2	8.0	0
AMS-4	Spaced sides and bottom	46	43	30-1/4	25	5.7	8.3
ARS-1	Solid sides and spaced bottom	40	47	30	24-1/4	8.7	0
Comm.-1	Vented fiberboard over wide spaced sides and bottom	48	47-1/2	36	32	1.2	0.7
Comm.-3	Vented fiberboard over wide spaced sides and bottom	48	48	29-1/2	24	0.5	0.7
Comm.-2	Solid sides and bottom with 1-1/2" slot around bottom 3/	48	48	29	24	0	5.2
Comm.-2M (2 Modified)	Solid sides and bottom, no vents around bottom 4/	48	48	29	24	0	0
Standard apple box	Free area in bottom varies somewhat with type of bottom shook used	12-1/4	19-1/2	10-3/4	10-1/2	10.0	0

1/ Spacing refers to openings from 5/8" to 3/4" on the bottom; side spacing means from 5/8" to approximately 4".

2/ The removable 9-1/2" high sections are removed for filling, but were kept in place for the cooling tests.

3/ Sides and bottom were lined with paper for test to eliminate effect of air entry through small cracks in the pallet box.

4/ Paper lined to form solid interior.

from the center of the box to the face or faces of the mass of apples where heat was transferred to the air. The most important variables influencing the cooling accomplished by convection are the temperature and quantity of air passing the apples. The provisions for air to enter the box have a great effect on these variables.

When conduction is the sole means of heat removal, the cooling performance will vary almost as the square of the distance from the center to the nearest face where heat can be transferred to the air. If the heat can be disposed of through more than two parallel faces, the relationship becomes more complex. If the distance from the center to one set of parallel faces is much less than the distance to the other pair of parallel faces, then most of the heat is conducted to the nearest faces and the influence of the farthest pair is slight. All stacks of pallet boxes were placed, as in normal commercial practice, tightly together in the row so that the backs and fronts of the boxes had little access to air. It does not seem reasonable that very much heat can be conducted through these surfaces; therefore, the length of the box does not appear to be a variable entering into these cooling studies.

The depth of the box may also influence the cooling accomplished by convection. The depth may affect the quantity of air which passes through the fruit. As the air quantity is decreased, the air temperature rise as it passes through the fruit increases. As a result, the temperature difference between the air and the fruit is smaller and the cooling time becomes greater.

Provisions to let air into the box, to accomplish as much cooling as possible by convection, is of prime importance. For that reason, the boxes selected have a wide variation in the manner in which air may enter. In some, the air passes through the sides, others the bottom, and some through both. Yet the most important cooling function is the total space for air to enter. Such free area has been calculated for the bottom and the sides of each type of box. This calculation deducts the area of cross members where spaced sides or bottoms are used. This measure seems to be the best index to show how accessible the box is to air flow.

Cooling Rates of Different Pallet Boxes

Half-cooling time is the time required to reduce the temperature of the fruit one-half the way from the initial fruit temperature to cold storage air temperature.

Approach temperature is the temperature difference between the cooled commodity and the adjacent air after equilibrium is reached.

The half-cooling time for the standard boxes showed a considerable difference between the 2 test locations (table 3). Previous tests of the cooling performance of pallet loads of unpacked apples in standard boxes showed half-cooling times that ranged from 15.4 to 23.4 hours. In the light of previous experience, the performance at test location No. 1 approaches the

best results that have been observed for cooling apples. The performance at the second test location was slower than any previously observed tests of cooling unpacked apples in pallet loads of standard boxes. Therefore, the results are not directly comparable.

Table 3.--Half-cooling time and approach temperature for 9 types of pallet boxes and for pallet loads of unpacked standard apple boxes

Type of box	Half-cooling time 1/		Approach temperature 2/
	Hours	Index 3/	Degrees F.
Test No. 1			
Standard apple box (loose)	16.1	100	0.7
Comm.-3 (fiberboard liners)	29.8	185	.7
Comm.-2 (1½" bottom slot)	26.7	166	.9
Comm.-2M (no vents)	29.2	181	.9
AMS-2 (spaced sides, solid bottom)	15.5	96	.8
ARS-1 (solid sides, spaced bottom)	15.6	97	.8
Test No. 2			
Standard apple box (loose)	30.9	100	.7
Comm.-1 (fiberboard liners)	33.0	107	.5
AMS-1 (solid sides, spaced bottom)	32.4	105	.5
AMS-3 (spaced bottom, no pallet)	32.4	105	.6
AMS-4 (spaced sides and bottom)	10.0	32	.2

1/ Half-cooling time is the time required to reduce the temperature of the fruit one-half the way from the initial fruit temperature to cold storage air temperature.
2/ The approach temperature is the temperature difference between the cooled commodity and the adjacent air after equilibrium is reached.
3/ Time for standard apple box = 100.

The first test shows that the 2 boxes with good ventilation--the box with solid sides and spaced bottom, and the box with solid bottom and spaced sides--cooled slightly faster than pallet loads of standard boxes. The other boxes in this test, which had a low percentage of free area, took from 66 to 85 percent longer to cool than the standard apple boxes.

The pallet box with spaced sides and spaced bottom, and with the greatest free area of any box in the 2 tests, was far superior to all boxes

in the second test. The remaining boxes cooled slightly slower than the pallet loads of standard apple boxes.

In both tests all types of boxes approached the air temperature closer than one degree F. This is considered satisfactory performance. In general, the approach temperature is very similar to that encountered with pallet loads of standard apple boxes.

Pallet Box Construction Recommendations

Although there are some types of boxes in the test that require 3 times as long to cool as others, the half-cooling time of the slowest is not prohibitive of use. Previous studies made by the Department of cooling rates of apples wrapped and packed in standard boxes have showed the half-cooling time for these boxes on pallets to range from 45 to 66 hours. In these same tests packed apples stacked in individual rows with air circulation space between each row required a half-cooling time of from 27 to 50 hours. From these figures, it appears that the poorest cooling in pallet boxes is generally faster than all but the very best performance of standard pack from "hot" fruit as it comes from the field and then is placed in cold storage.

While it appears from the present cooling studies that all of the pallet boxes tested could be recommended as giving results as good as a standard pack of "hot" fruit, it must be remembered that investment in equipment for refrigerating a plant is expensive. Every possible means should be devised for using the refrigeration machinery as efficiently as possible. It is only logical to select and use those features of pallet box construction that give greatest economy of refrigeration equipment. Some pallet boxes will use less refrigeration than others because the faster cooling rapidly reduces the heat of respiration given off by the fruit so that less total heat is generated and less total heat needs to be removed.

These tests indicate that a pallet box constructed with either sides or bottoms having approximately 8 to 11 percent free area will provide excellent cooling characteristics. A box constructed with this much free area in both sides and bottom will have substantially better cooling characteristics than the present standard container. When the apple industry adopted palletization, it accepted some penalty in cooling performance. Unpacked apples in standard boxes stacked in individual rows enjoy a half-cooling time about 50 percent of that required when placed in pallet loads. It is possible that proper pallet box design offers an opportunity to regain some of the cooling performance that was lost when palletized handling was adopted.

The test indicates that side ventilation may be as effective as bottom. Yet, this conclusion is subject to some qualification. The pallet box with spaced sides and solid bottom, and the box with solid sides and spaced bottom, representative of these two situations, differ somewhat in dimensions and percent of free area, and the difference in both cases favors the box which has the side ventilation. However, the performance of the box with side

ventilation was very good and illustrates the effectiveness of side ventilation.

The pallet box with solid sides and bottom, but with an air space around the bottom, had the best performance of those boxes where the percentage of free area is low. It was, however, definitely much slower than the well-ventilated boxes that were included in the same test.

It is possible that boxes with fiberboard liners could be provided with more slots and bring the free area of both bottoms and sides to about 5 percent. Further work should be done along this line, as there is good possibility that cooling performance of this type of pallet box could be greatly improved.

Recommended Practices in Storage Room

The handling of pallet boxes in storage should apparently follow the best practices for handling pallet loads of standard boxes of apples.

Previous studies have shown that when containers of fruit are placed directly against outside walls, heat is transmitted through the wall into the container and there is no opportunity for room air to pick up the heat before it enters the pallet box. Fruit in such locations may be 1 or 2 degrees higher or lower than fruit in adjoining boxes depending on outside temperature. Stacks should be at least 6 inches away from outside walls to eliminate this difficulty. Similar space should be left near inside walls. Placing the box against these walls interfers with circulation past the stack and the ability for air to enter or leave the fork spaces. Rows should be run straight, with the aid of floor markers, to provide approximately a 5-inch space between rows of boxes.

Stack rows should run parallel to the direction of air flow in the storage. Previous tests have indicated that more uniform holding temperatures are obtained when this is done, if 2-way pallets are used in the box construction. A row of boxes constitutes an almost solid dam to the flow of air. Placing the stacks perpendicular to the normal airflow pattern results in interference with uniform airflow.

Stack rows should consist of similar pallet boxes so the fork space between boxes is continuous from front to back of the row, allowing a continuous air channel. Although boxes may be very close to the same height, the difference is cumulative and at the upper positions in the stack a 1-inch difference in box height can serve to blank off the channels formed by the fork space.

BRUISING

The first bruising studies of apples in pallet boxes in Washington were made in 1950 by the Washington State Apple Commission. In 1955, the Agricultural Research Service began more detailed studies on bruising at the Tree Fruit Experiment Station at Wenatchee. These studies were expanded during the 1956 harvest season and again in 1957. They were supplemented by the research of the Agricultural Marketing Service in 1957.

Early Studies

In 1956, the Agricultural Research Service made studies with bruise-free fruit placed carefully in a deep pallet box and found that the bruising was directly proportional to the depth of the boxes. However, it was determined that the average amount of bruising in a 38-inch deep pallet box was almost identical to that when the standard apple box was used. In 1957, more extensive studies were made during harvest of 2,000 standard box equivalents of apples in pallet boxes of 23 to 27 loose field or standard box capacity. Bruising from picking, hauling, storing and emptying the pallet boxes onto a commercial packing line was included. All flattened areas were considered as bruises whether discolored or not.

Results

Bruising or marking occurring on Golden Delicious apples harvested in pallet boxes were associated with the various stages as follows:

	Percent
Picking	32
Hauling	1
Storage	31
Emptying.	36

Comparisons made between 32- and 30-inch high pallet boxes showed no difference in bruising.

Hauling consisted of moving pallet boxes out of the orchard with a tractor-mounted, high-lift fork, decking them 2 high, hauling to the loading area, loading on a highway truck and hauling 2 to 3 miles to the storage plant. Cold storage bruises were attributed to the weight of apples resting on each other in pallet boxes for a period of 9 weeks. The pallet boxes were emptied with an inverting-type commercial box dumper (fig. 13).

Apples handled in pallet-box were compared with handling of standard boxes which were placed on pallets after being filled in the orchard and then hauled to cold storage. The boxed apples were stored as long as those in pallet boxes and were emptied onto a commercial packing line with a stack-breaking type automatic box dumper.

The Golden Delicious apples harvested in pallet boxes showed 5 percent less bruising as they went onto the packing line than the comparable apples harvested in standard boxes. The apples handled in standard boxes received 38 percent of their bruising during picking and hauling and 62 percent in storage and emptying compared with 33 percent and 67 percent respectively for the fruit handled in pallet boxes.

Red Delicious apples harvested in pallet boxes showed 18 percent less bruising than similar apples harvested in standard boxes. Pallet box and standard box-picked Winesaps were almost the same. Those in pallet boxes showed only 1 percent less bruising than those in field boxes. The average of all 3 varieties harvested in pallet boxes showed 7 percent less bruising than those harvested in field boxes.

Current Studies

During the latter part of the commercial harvest in 1957, bruise studies were started on 11 different types of pallet boxes. Four of each type of box were used. Two equal test lots were harvested separately to comprise 2 different tests. Fruit from 3 or more trees was picked and emptied into one pallet box at a time by several pickers until that box was filled. The other test boxes were filled in the same way from the same trees. Following commercial practice the fruit was hauled to the edge of the orchard, placed on a flat-bed trailer and hauled to the warehouse where bruises in a quarter-box sample of apples were carefully counted without disturbing the apples in the rest of the pallet box. Only bruises larger than one-quarter inch were counted.

While the fruit was being harvested in the pallet boxes, a check sample was being harvested into individual field boxes which had been placed empty on pallets and filled so that the individual boxes were not picked up after they were filled. They were thus filled 3 deep on the pallet, and 2 pallets at a time were hauled from the orchard. This is the best commercial practice for handling field or standard boxes.

Another study was made of a specially designed pallet box. Each quarter of the box was made with a different type of side and bottom structure and each corner with a different type of construction. Bruise-free apples were placed in a pallet box which was run over an obstacle course by a lift truck. Bruises were then carefully counted and evaluated. This was repeated six times.

Results

The studies showed that pallet box handling caused less bruising than the individual box handling of the most careful type. Bruising against the sides of pallet boxes amounted to 19.4 bruises per 100 apples compared with 23.9 against the sides of individual apple boxes; against the bottom of pallet boxes there were 15.8 bruises per 100 apples touching the bottom compared with 19 bruises per 100 apples touching the bottom of the individual boxes.

The average of all bruising in pallet boxes ranged from 32.3 to 55.3 bruises per 100 apples compared with 58 in small boxes.

Generally the deeper the pallet box the greater the bruising. There was one exception. The deepest of the pallet boxes, 34 inches, did not have much more bruising than the 24-inch deep pallet box lined with corrugated board. This may have been the result of using a removable 10-inch board on the two sides of the pallet box that made it easier for pickers to place their fruit into the box. The box also was of more sturdy construction than the other deep pallet boxes tested. Experimental error may also account for some of the apparent disagreement. All of the pallet boxes showed less bruising than carefully handled small field boxes. Bruises of one-quarter inch and larger per 100 apples occurring during picking and handling in pallet boxes and field boxes are shown below: 4/

Description of pallet box	Bruises per 100 apples
24" deep, lined with corrugated board	32.3
27" deep, lined with corrugated board	46.5
32" deep, lined with corrugated board	55.3
24" deep, not lined with corrugated board . .	47.3
34" deep, not lined--10-inch removable board.	35.3
Carefully handled small field box	58.0

The supplementary studies were designed to give more specific answers on which type of construction on the sides, the bottom, and corners of boxes would be less conducive to bruising. The effect of side construction on bruising of apples was studied by determining the number of bruises occurring per 100 apples touching different types of side structure of 24-inch deep pallet boxes. The type of side construction, the bruises, and bruise index are shown below:

Description of side construction	Bruises per 100 apples	Index 1/
	Number	
Wide slat, corrugated board liners.	5.1	27
Spaced vertical slats, eased edges, corrugated liners.	13.4	70
Plywood, corrugated board liners.	13.6	71
Solid, horizontal slats, bullnose edges . . .	18.5	97
Plywood	21.1	110
Solid horizontal slats, eased edges	21.5	113
Spaced horizontal slats, bullnose edges . . .	23.9	125
Spaced vertical slats, bullnose edges	26.0	136

1/ Based on 19.1 bruises = 100.

4/ These bruise tests will be completed after 5 months of holding in cold storage to ascertain the extent of bruising due to pressures while standing in storage and dumping. Complete results will be reported at the completion of this project.

These data indicate that the corrugated board was a definite asset in preventing bruising against the sides. Surprisingly, the solid plywood side did not show up quite as well as might be thought when compared with 1 by 6 boards with bullnosed edges. This difference might be due to experimental error.

The use of corrugated board liners over plywood had a definite advantage in preventing bruising of bottom apples. Wide-spaced slats with corrugated board over them did not show up as well. Two types of bullnosing were tried on bottom boards spaced about 3/4-inch apart. One had a radius equal to half the thickness of the board, the other had a radius equal to the full-thickness of the board. The latter appeared to be definitely better. The effect of bottom construction on bruising of apples was studied by determining the number of bruises occurring per 100 apples touching different types of bottom structure of 24-inch deep pallet boxes. The type of bottom construction, the number of bruises, and the bruise index are given below:

Description of bottom construction	Bruises per 100 apples	Index 1/
	Number	
Plywood, corrugated board liner	9.8	45
Plywood	20.3	94
Wide-spaced slats, corrugated board liner	22.3	104
Spaced slats, bullnosed edges:		
1. Radius = 1/2 thickness of board.	27.1	126
2. Radius = thickness of board.	21.4	100
Solid floor, slats with eased edges	25.0	116

1/ 21.5 bruises = 100.

Records showed that the diagonal corner post was apt to cause least bruising. The next best corner was a 2 by 4 with a rounded exposed edge. The use of 1 by 4's in the corners or a construction with no corner posts inside the box rated third.

PALLET BOX PERFORMANCE AND BREAKAGE

The period of study to date, which consists only of a part of the 1957-58 season, is still too short to make any significant analysis of the durability of any particularly designed pallet box. Records were kept of the number of pallet boxes damaged and the causes of this damage at 8 commercial apple storage and packinghouses located in Washington. Records were also kept on the experimental boxes. These packinghouses have had no experience with pallet boxes prior to this season, so the records reflect only the damage to the pallet boxes during their first year of use. Failures may increase as the pallet boxes get older and require additional repairs. Also, since pallet boxes are a new development and there has been little experience in construction or handling, a higher failure may have resulted than there will be with more experience.

Of 24,200 pallet boxes used commercially in Washington during the 1957-58 season, three-tenths of 1 percent of them were damaged beyond repair; 2.7 percent incurred repairable damage, most of which was minor; and 7 percent of those using corrugated fiberboard liners showed liner damage.

The incidence of damage beyond repair to pallet boxes was small. The pallet boxes generally were of rather heavy construction and durable enough to stand up under field usage. When a pallet box was discarded because it was totally damaged, it was generally the result of an accident. For example, 48 out of the 67 discarded, resulted from falls off of motor trucks, tipping of high stacks by wind, etc. The other 19 resulted from carelessness or the failure to operate handling and dumping equipment satisfactorily.

Causes of damage associated generally with faulty material and poor construction: 63 percent. The balance, or 37 percent, was damaged during normal handling, storage, and dumping.

Although only 3 of the 8 plants used pallet box liners, the commercial boxes with liners exceeded half of the commercial number in use. The liner was favored as a means of reducing bruising. However, these liners were not sufficiently wetproof after the hot sun had melted their wax coating and about 60 percent of the damage was incurred because of moisture. Wide spacing between the boards in the frame of the pallet box allowed the liners to bulge out, and accounted for 20 percent of the liner damage. Wind, rodents, and other factors were responsible for the remainder of the damage.

COMPARATIVE COSTS OF DIFFERENT METHODS OF HANDLING PALLET BOXES

One of the objectives of the research with pallet boxes was to determine, through properly conducted time studies, the labor requirements for handling apples. The resulting data are to be made available to operators of orchards and packing plants as criteria for choosing pallet boxes and handling methods and equipment for these pallet boxes. The nature of the present report includes the results of this study to date and is far from complete. Full data, however, will be published upon completion of the project.

The handling of large numbers of pallet boxes was studied through the various cycles of operation. Comparative data are presented in table 4 for the pallet box which is 48- x 48- x 29-inches in size, the deepest of the pallet boxes found in commercial use, 48- x 47½- x 36-inches high, and the 48-box unit loads of standard boxes of apples handled on 40- x 48-inch pallets.

Methods of Handling

In the orchard pallet boxes were handled with tractors with rear mounted forks. These vehicles were used to distribute empty pallet boxes to pickers, to move filled ones to the edge of the orchard, and to load them on different

Table 4.--Labor and equipment requirements and costs per 1,000 unpacked boxes of fruit for alternative methods of handling two different size pallet boxes and 48-box pallet loads of standard boxes from the orchard through the storage and packing house (preliminary)

Box type and method	Elapsed time	Labor and equipment requirements: Equipment time	Labor and equipment requirements: Total labor 4/	Labor and equipment costs: Equipment	Labor and equipment costs: Labor 5/	Labor and equipment costs: Total cost
	Hours	Machine-hours	Man-hours	Dollars	Dollars	Dollars
Comm.-2 (48- x 48- x 29-inch pallet box) 1/						
Orchard trailer with jeep	18.55	18.24	25.07	121.38	158.72	280.10
Highway truck (13-ft. bed)	17.93	16.96	24.45	120.47	157.69	278.07
Highway truck (16-ft. bed)	17.39	16.56	23.91	119.79	156.80	276.59
Straddle truck	16.15	15.84	21.80	128.52	153.55	282.07
Straddle trailer	16.63	16.32	22.28	127.18	154.27	281.45
Comm.-1 (48- x 47½- x 36-inch pallet box) 2/						
Orchard trailer with jeep	16.03	15.72	22.31	110.44	154.25	264.69
Highway truck (13-ft. bed)	15.68	14.85	21.96	109.97	153.73	263.70
Highway truck (16-ft. bed)	15.18	14.47	21.46	109.25	152.97	262.22
Straddle truck	14.30	13.99	19.95	116.04	150.65	266.69
Straddle trailer	14.76	14.45	20.41	115.52	151.33	266.85
48-box pallet 3/						
Orchard trailer with jeep	24.07	16.18	26.70	182.82	162.96	345.78
Highway truck (13-ft. bed)	24.80	16.22	27.43	183.74	164.05	347.79
Highway truck (16-ft. bed)	24.05	15.64	26.68	182.71	162.93	345.64
Straddle truck	22.62	14.73	24.36	189.80	159.36	349.16
Straddle trailer	22.77	14.88	24.51	186.19	159.58	345.77

1/ 27.1-box capacity.
2/ 37.1-box capacity.
3/ When fruit was handled it was handled in loads of 48 loose standard boxes and 40 packed standard boxes.
4/ Does not include picking since this is done on a piece work basis.
5/ Includes cost of picking at 12¢ per standard loose box equivalent.

hauling vehicles. Field or standard boxes were moved to the edge of the orchard on pallets. They were either loaded onto, or placed into a block for picking up by various types of transportation vehicles. All handling at the storage and packinghouse was done by industrial forklift trucks. Loose field or standard boxes were handled in 48-box loads on 40- by 48-inch pallets. Pallet boxes were handled two at a time. Generally the fruit was moved directly to storage. Later it was moved to the dumper. After packing and segregating, it was moved back into cold storage on pallets. At the appropriate time the packed fruit was moved to railroad cars on pallets for loading out.

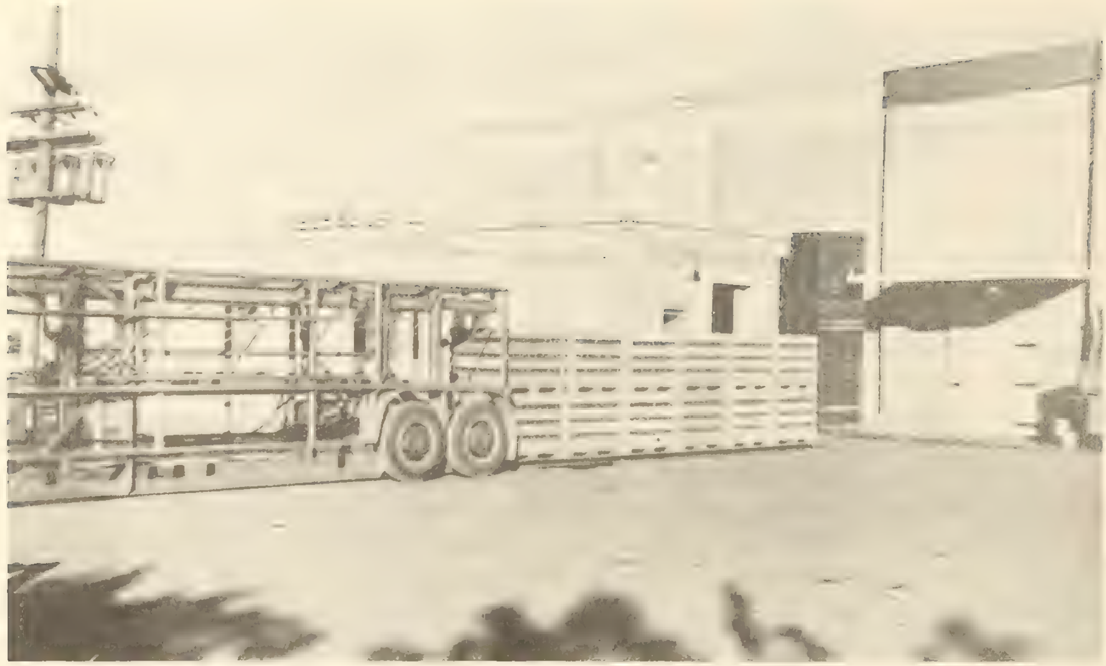
For the comparisons made in this report, it is assumed that the cycle of operations consists of loading empty boxes or pallet boxes onto various transporting vehicles (figs. 17, 18, and 19), transporting empties to the orchard, approximately 4 miles, or 20,000 feet, from the storage and packinghouse, unloading transportation vehicles, transporting empty containers approximately 500 feet into the orchard, filling the containers, transporting full containers 500 feet from picking point to loading area at the edge of the orchard, loading transporting vehicles (fig. 20), transporting full boxes or pallet boxes 20,000 feet back to the storage and packinghouse, unload vehicles, transporting a distance of 200 feet from the transportation equipment to cold storage (fig. 21), transporting full containers of fruit a distance of 200 feet from storage to the dumper, dumping fruit, returning empties to box storage, segregating packed fruit, transporting packed fruit back to storage a distance of 160 feet and moving the packed fruit from storage to the refrigerator car for loading a distance of 110 feet.

In connection with the use of the various handling methods it was assumed that the dumping rate was 400 loose standard boxes, or the equivalent, when pallet boxes were being moved to the packing line.

Labor

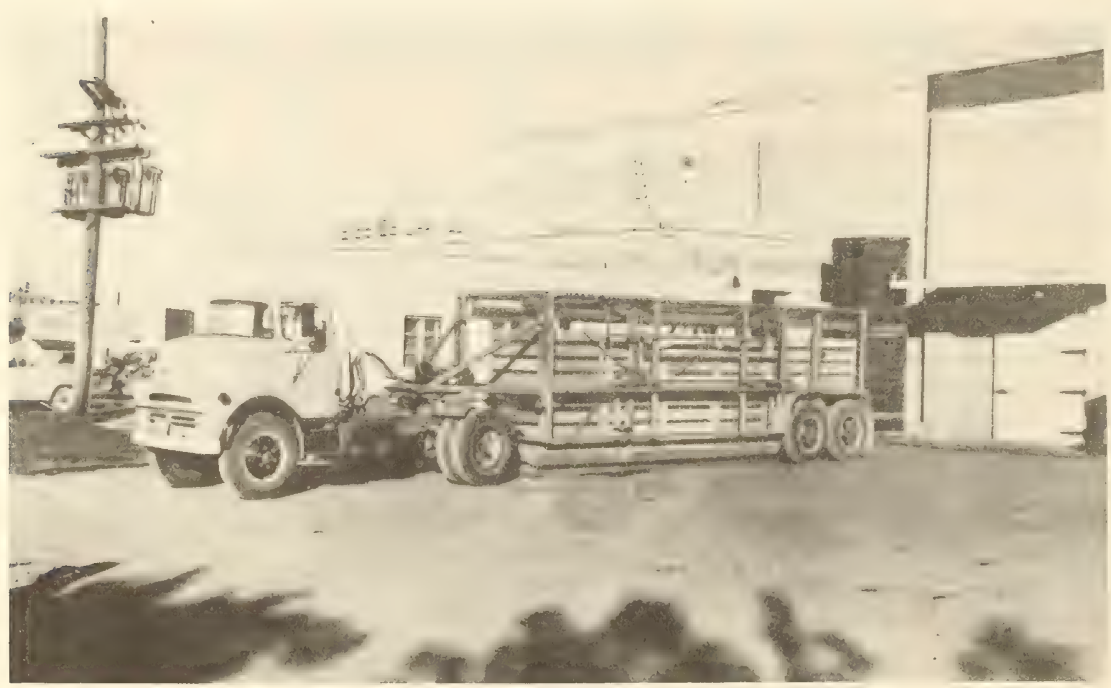
Time studies were made of the various operations involved in moving containers to the orchard, moving pallet loads or pallet boxes of fruit from orchard to storage and packinghouse, and in moving fruit and container into, within, and out of these houses. This was done in order to determine the labor inputs required for these operations. Accepted time study techniques were used with allowances made for fatigue and personal needs. The total labor requirements shown in table 4, in addition to productive labor, include unproductive time of workers caused by different rates of productivity of other crew members and machine regulated wait time.

For the respective methods shown in the table, the labor requirements when handling loose standard boxes in 48-box pallet loads are higher than that for the 29-inch high pallet box and somewhat higher than that for the 36-inch high pallet box.



NEG. BN-5801

Figure 17.--Straddle trailer being backed over a load of empty pallet boxes prior to pick up and transportation to the orchard.



NEG. BN-5802

Figure 18.--Straddle trailer positioned over loads of empty pallet boxes ready for pick up prior to transportation to the orchard.

NEG. BN-5803

Figure 19.--Empty pallet boxes being loaded onto a highway truck for movement to the orchard.

NEG. BN-5804

Figure 20.--Industrial forklift truck loading full pallet boxes onto a highway truck in a loading pit at the edge of the orchard.

NEG. BN-5805

Figure 21.--Pallet boxes of apples being placed in storage in one of the commercial storages.

Hourly wage rates used in these comparisons were based on $1.50 for all labor, except forklift truck operators, who received $1.75 per hour. In the cost comparisons picking was computed at 12¢ per field or loose standard box.

Equipment

Equipment requirements are based on the use time associated with the various operations in connection with handling fruit from the orchard to and through the storage and packinghouse. These machine inputs are shown in table 4 as equipment times and reflect industry averages.

The costs of using this equipment include both ownership and operation costs. Ownership costs for the various pieces of equipment consisted of depreciation, interest, insurance, and taxes. For simplicity, depreciation was formulated on a straight line basis; therefore, the total cost of the equipment was divided by its expected life. Interest was based on 6 percent of one-half the initial cost of the materials-handling equipment. Tax rates were computed on a basis of 46 mills based on 22 percent of the original purchase price. This mill rate was derived from taking an average of the municipal and rural tax levies for Yakima County. Insurance rates were obtained from published rates for this general area.

Costs of operation for materials-handling equipment fluctuate with, and are associated directly to, the estimated number of hours that each piece of equipment is used. These costs included gas and oil for internal combustion equipment, electricity for all electrical units, and maintenance costs such as preventive maintenance, overhaul and repair. 5/ Since maintenance costs are based on the estimated hours of use, deterioration of equipment has been included under depreciation of equipment.

To estimate costs per hour, the annual hours of use for each type of equipment were estimated for the season. These assumed hours of use are based on observations in various plants of the length of the fruit-handling season. They reflect an average for the industry rather than a precise figure for a specific volume of business. An individual operator would have to determine his time-use of equipment to estimate his hourly costs for equipment. In this case they would be directly related to the volume of fruit handled.

As used in this section actual cost of equipment, applied to any specific operation, was based on the relationship between the cost per hour of a specific piece of equipment and the actual time of performance of the operation as derived from the time study. The unit times in the time study were based on a per 1,000 unpacked apple box equivalent basis; therefore, following the preceding relationship, equipment costs are also based on a per 1,000 box equivalent basis.

Equipment costs include all cycles of operation which the various units encounter throughout the complete overall cycle for fruit movement from orchard into, within, and out of apple storage and packing plants.

Comparison of Methods and Equipment

Table 4 presents the comparative labor and equipment costs incurred in moving 1,000 equivalent unpacked boxes of apples in 3 different containers from the orchard into, within, and out of apple storage and packinghouses by use of 5 combinations of handling equipment. Included in these costs are the charges for picking the fruit.

It is rather surprising that the combined labor and equipment costs for the various methods of handling a specific container are not too different. For example, for the pallet box shown as Comm.-2 the total costs range from $277 to $282 per 1,000 equivalent standard boxes, for the Comm.-1 these costs range from $262 to $267, and for standard boxes handled on pallets these costs range from $346 to $349.

On the basis of these figures if a grower-packer has the correct equipment on hand he should be able to effect a saving of between $70 and $85 per 1,000 equivalent standard boxes by shifting from standard boxes on

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5/ Gasoline computed at 25¢ per gallon, oil at 40¢ per quart, and electricity at $0.015 per kilowatt hour.

pallets to pallet box handling. On a volume of 100,000 equivalent standard boxes, an annual saving of between $7,000 and $8,500 might be expected. This does not include added value to the fruit by preserving its inherent quality and savings from greater utilization of storage space. Many storage and packinghouse operators might be able to increase their volume of business by nearly 20 percent without any expansion of plant or any additional capital investment in facilities. This could amount to a saving of about 5¢ per box.

Pallet Boxes Save Cold Storage Space

Pallet boxes make more efficient use of cold storage or other storage space. This is shown in figure 22 where two pallet boxes and 48 standard boxes have equal fruit-holding capacity. The floor area of the pallet boxes is 40- by 47-inches and of the standard boxes, on the 40- by 48-inch pallet, is 40- by 48 3/4-inches. The pallet boxes are 62 inches high and the standard boxes with pallet are 72 inches. The standard boxes and the pallet necessary for handling them with forklift equipment occupy 20 percent more volume than the pallet boxes. Cold storage capacity therefore can be increased about 20 percent with pallet boxes if space is used as effectively as with standard boxes.

NEG. BN-5806

Figure 22.--The two pallet boxes on the left hold an equal amount of fruit to the 48 standard box pallet load on the right. Both stacks occupy essentially the same floor space. The pallet boxes require less space vertically.

EVALUATION OF PRESENT PALLET BOXES

Commercial operators were generally satisfied and enthusiastic about the use of pallet boxes. Those already using pallet boxes intend to expand their use, many during the coming year. This satisfaction arises not only from the fact that it is less costly to handle fruit, but the pallet boxes provide greater ease of handling. Harvesting is less tiring and the harvest operation requires smaller, more easily managed crews. This is important for smaller growers who do their own loading and hauling. The pickers generally were pleased with picking into pallet boxes, and results of bruise studies are favorable. Costs of containers are less--only about one-half that for field or standard boxes. These advantages, together with the increasing need for picking containers, as the industry shifts to fiberboard shipping containers, are hastening the adoption of harvesting in pallet boxes.

The most noticeable shortcoming of pallet boxes was their lack of strength. Nearly all of the commercial users included this in their suggestions for improvements. The strength could be added by heavier materials, possibly the use of kiln-dried lumber, more nailing, use of screws or bolts, and designs to prevent racking and springing when handled with forklift equipment.

Racking, or skewing, of pallet boxes in some cases was a major problem, particularly as it affected dumping. At times the worker tending the dumper had to use a pinch bar to get the racked boxes into the machine.

A need, not as noticeable as the others but important, was to prevent the bottoms from springing when lifted by the forks of the handling equipment. The easiest way of doing this was to fasten the pallet in the center to the side panel boards or extend the side panel boards down against the pallet. Another way of avoiding this problem was to use lift-truck forks long enough to extend completely through the pallet so that, as the forks of the lift truck were tilted back, they would not lift the full weight of fruit with the tip end of the forks on one deck board. Forks extending beyond the pallet could cause damage to adjacent pallet boxes in close stacking. Forks 47 inches long are the most suitable for 47- to 48-inch square pallet boxes.

For orchard use a high fork-entry space on the pallet boxes is needed. On rough and irregular terrain this is much more important than at the warehouse. Experience indicates that the fork openings should be about 3½ inches high. The four-way entry pallet has definite advantages in the orchard, but the need for this added expense can be avoided by properly placing the empty 2-way entry pallet boxes for pick up. This placement would include having the direction of fork-entry directly up-hill. Pallets so placed that fork-entry was sideways to the slope, were difficult to pick up in wet weather.

One of the important weaknesses in lined pallet boxes was the lack of durability in the liners. They were not sufficiently water resistant particularly after they had been exposed to the sun. A better liner material is needed.

The largest of the commercial pallet boxes, which contained about 37 loose, field boxes, appeared to be too large for a tractor fork attachment to handle two at a time. All of the smaller pallet boxes could be handled by twos. Thus there was some loss of efficiency with the larger container.

An expensive part of the pallet box operation proved to be dumping. None of the dumpers presently used were fully automatic, some of them requiring 2 operators. It is possible that a change in pallet box design might be made to simplify dumping or that the dumping procedure itself could be modified as it was in the case of one plant that made a simple, tilting type dumper at considerably less expense.

SUGGESTIONS FOR IMPROVING PALLET BOX CONSTRUCTION AND DESIGN

The most frequently suggested improvement in pallet box design was to make the boxes sturdier. Sturdier construction can be obtained in a number of ways. First, the top and bottom panel boards should be the largest and the heaviest boards in the box. Strength can be increased by using rough lumber rather than finished. However, unless the pallet box is lined with fiberboard or other material the inside surface should be smooth. The diagonally cut corner post is stronger and has a slight advantage in reducing bruising and makes it a little easier to stack the pallet boxes in storage (fig. 23). To add to the strength and help the pallet boxes resist racking, it would be desirable to increase the amount of nailing space or use glue and screws or bolts.

The pallet box used in the orchard needs to be stronger and sturdier than the one that might be used only for handling around the warehouse. If it ever becomes practical to size apples before placing them in storage, it is possible that a pallet box especially designed for use in the orchard and for hauling to storage might be desirable.

For the warehouse, the maximum size of the pallet box should be designed to specifically fit the cold storage rooms. In older storages the dimensions might well be affected by supporting post centers. The height should be determined by the height of the ceilings in the storage, and preferably be such as to give an even number of pallet boxes so that the forklift truck can handle near its maximum rated capacity during the storage operations.

If pallet boxes are to be used only at the storage plant they should be designed with low fork entry space. Each additional inch of depth obtained in a 24-inch deep box by reducing fork entry space is equivalent to approximately a 4-percent increase in cold storage capacity, a financial consideration well worth evaluating. The fork entry space might be reduced by using 3 by 4's on their side and eliminating the skid boards underneath the pallet. This would increase the storage capacity about 1-1/2 inches per pallet box or nearly 6 percent.

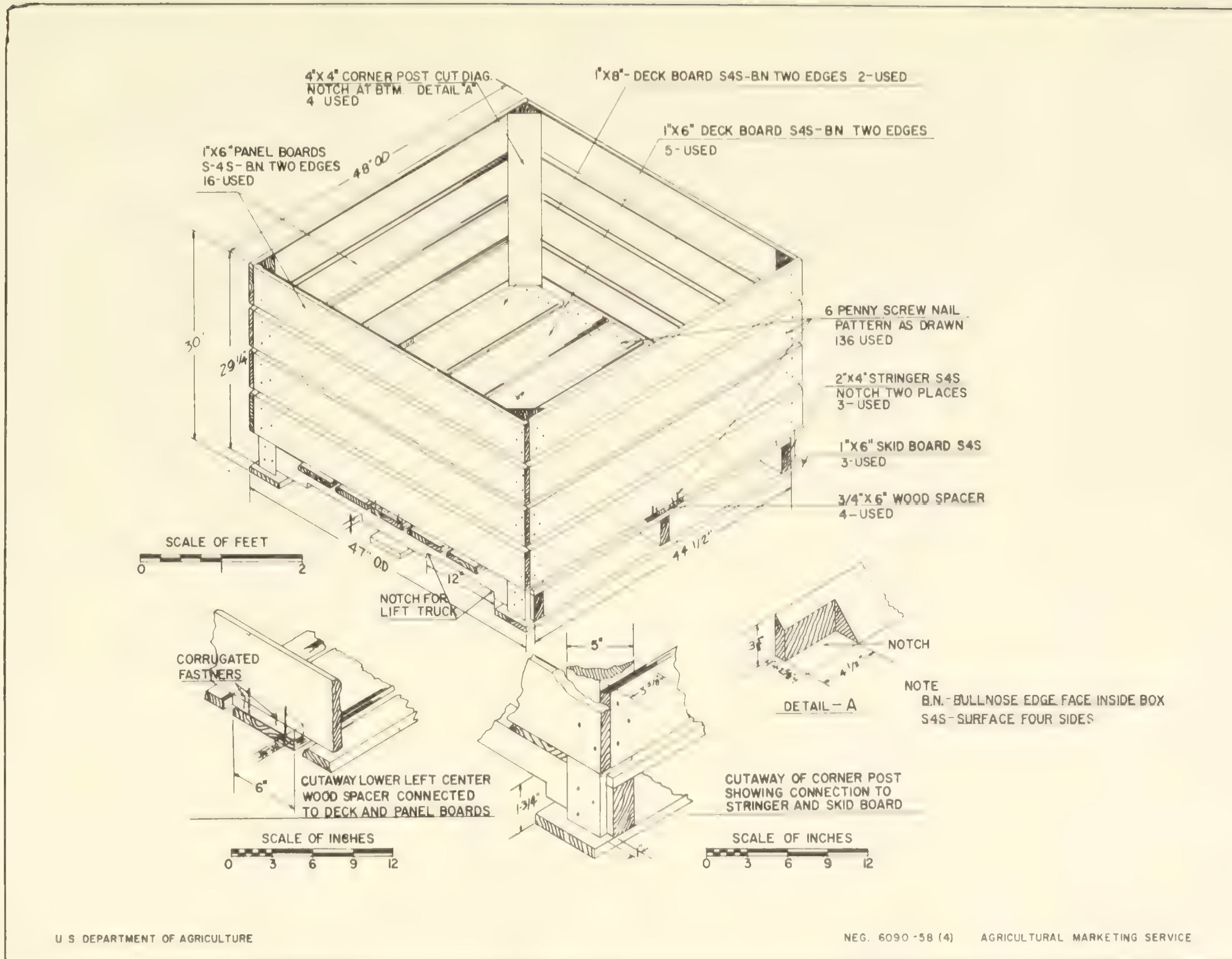


Figure 23.--This illustration shows the design features for a pallet box having excellent cooling characteristics.

Another consideration for possible future designs for pallet boxes is the elimination of the pallet completely by using modified forks to lift against rails on the sides of the pallet boxes providing that they can be properly cooled. Modification of handling equipment in this way theoretically could increase cold storage capacity approximately 14 percent over present pallet boxes using regular fork entry space. Since the saving in cold storage space that occurs with present pallet boxes amounts to about 20 percent, it is theoretically possible to increase cold storage capacity in some plants with the right designed pallet box to a point about 40 percent over that when standard boxes are stored on pallets.

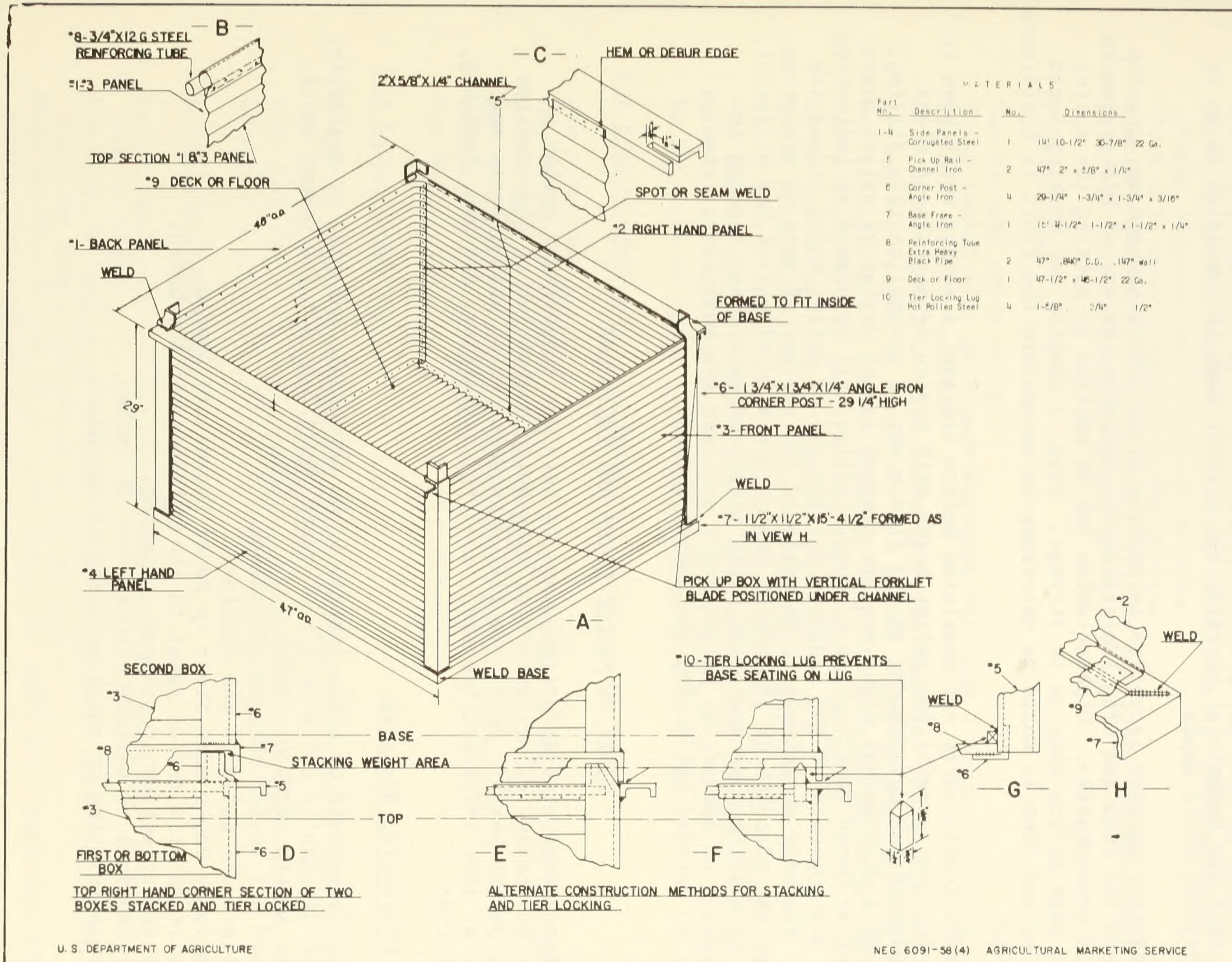
A possibility that might be explored for future pallet box design is to have an airtight pallet box made of metal (fig. 24). The thinner walls of metal would increase the storage at least one bushel per pallet box. The metal might give adequate cooling and by devising a fairly tight fitting plastic cover to fit over the pallet box it might be possible to provide the equivalent of modified atmosphere storage similar to that obtained by placing a polyethylene liner on a standard box of fruit. While such a pallet box is not recommended now, it is one that is judged to be worthy of some consideration.

Future use of pallet boxes may result in the need for a pallet box that can be disassembled and reshipped or one that will be low enough in price to be discarded.

A knock-down type pallet box could have value in storing fiberboard shipping containers by using the supporting structure of a side or especially made posts to give stacking strength. A future possibility might be a pallet box to be used for shipping tray-packed fruit to eastern markets. Theoretically the strength of the fiber in the container can be reduced, because the stacking strength would be obtained by the pallet box, making it possible to save approximately 10¢ per packed box in container cost. This saving might be increased if trays or a rack could be designed to hold the fruit so that the packed trays or racks could be shipped in the pallet box without the expense of a master container. Similar experiments are now under consideration by the cannery industry to ship direct to retail stores without master containers.

It would appear for most ideal pallet box design that a different pallet box would be desirable for orchard and for warehouse use. For the orchard the pallet box needs to be heavier and should have higher fork entry space. For warehouse use the pallet box should be designed to fit the storage, should have no or low fork entry space, and can be lighter in construction because it will be handled over even floors by adequate capacity lift truck equipment. A special orchard pallet box would be dumped as it came from the orchard and returned for reuse making several trips per season. The fruit would have to be presized and placed in other containers before going to storage to make this feasible.

The practice of sizing fruit as it comes from the orchard which has been discussed for some years would increase storage capacity by removing the small, light colored, and off grade fruit from the fruit to be stored. In addition,



MATERIALS

Part No.	Description	No.	Dimensions
1-4	Side Panels - Corrugated Steel	1	14' 10-1/2" 30-7/8" 22 Ga.
5	Pick Up Rail - Channel Iron	2	47" 2" x 5/8" x 1/4"
6	Corner Post - Angle Iron	4	29-1/4" 1-3/4" x 1-3/4" x 3/16"
7	Base Frame - Angle Iron	1	15' 4-1/2" 1-1/2" x 1-1/2" x 1/4"
8	Reinforcing Tube Extra Heavy Black Pipe	2	47" .840" O.D. .147" wall
9	Deck or Floor	1	47-1/2" x 46-1/2" 22 Ga.
10	Tier Locking Lug Hot Rolled Steel	4	1-5/8" 3/4" 1/2"

Figure 24.--Design features of a corrugated steel pallet box which might be considered for use in the future.

it would permit a better marketing program because the larger sizes could be sold first and the smaller, longer keeping, sizes kept for the later market. The market and storage advantages of sizing into storage are great enough that several commercial operators are seriously considering this method of operating and, at least one commercial operator has already made the decision to do so with individual field boxes.

A possibly greater incentive to presize fruit before storage may develop if and when the Food and Drug Administration approves the use of Diphenylamine as a scald preventative. Diphenylamine can be applied by putting the apples through a wash before they go to storage. Thus, a dumping and washing would be required and then it would be necessary to accumulate the fruit in containers for storage.

To efficiently carry out presizing before storage, a method would have to be found for gently refilling pallet boxes with apples by mechanical means. Future research and development should find a way to accomplish this filling. In turn, this development might require changes in the design of pallet boxes. Thus, another broad ramification of possibilities will be opened up indicating that the developments of the industry for the use of pallet boxes indeed are dynamic. The many objectives to be achieved and variety of ways of achieving them makes the decision on the proper design and size of pallet box difficult. However, it will be made easier with the increased experience through the wider adoption of commercial pallet boxes and from the additional research that will be carried out during the coming season.

HINTS ON PALLET BOXES AND THEIR USE

Research conducted on pallet boxes to date has suggested a number of points to be considered in connection with doing a good job of construction and using pallet boxes. Below are listed suggestions on pallet boxes and their use as they influence bruising, cooling, durability, economy, handling, and selection:

For Preventing Bruising

Use fiberboard or other liners, if an acceptable material is available.
Use diagonally cut 4 by 4's or eased edged 2 by 4's for corner posts.
Use smooth surfaces inside.
Ease all inside corners of boards.
Clinch all nails on the outside.
Bullnose edges when floor or panel boards are spaced.
Bullnose at a radius equal to the thickness of the board.
Construct bottom to prevent springing.
Be cautious of outside heights over 36 inches.
Avoid twisting or rough handling of the boxes.

For Adequate Cooling

Vented bottoms and sides will equal the best cooling in field boxes.
Vent approximately 8 to 11 percent of either the side or bottom.
Unvented pallet boxes will provide approximately the cooling of hot packed standard pack boxes on pallets.
Stack with rows parallel to the airflow.
Keep approximately 4 to 6 inches of free air space between rows.
Leave at least 6-inch air space along all walls.

For Durability

Use two-way entry pallet.
Rough lumber will give more strength but then a liner must be used.
Maximize nailing surface.
Use dried lumber to give extra strength and nail holding capacity.
If undried lumber is used, dry new pallet boxes slowly before use.
Use straight grain lumber which is free of knots or has tight knots.
Use screws, bolts, and glue for fastening if possible.
Block bottom panel board against the pallet deck.
Avoid positioning pallet boxes on irregular surfaces.
Use a little extra care on the orchard pick up and stacking in storage.
Top and bottom side panel boards need more width than middle boards.
Do not start tilting before forks are clear through.
Do not push or force pallet boxes with tips of forks.

For Economy per unit of Capacity

Use a two-way pallet.
Use a low pallet with small fork entry space if for use in storage only.
Use as large pallet boxes as feasible.
Buy in quantity on a bid basis with specified quality.
Keep walls of pallet box thin.
Use inside framing.

For Ease of Handling

Pallet boxes with diagonal or 2 by 4 corner posts are a little easier to position one on top of another.
High fork entry space is desirable in orchard, not less than 3½ inches.
In orchard, position pallet for easy fork entry.

For Choosing Dimensions

Select the height to fit the storage ceiling height but definitely not over 36 inches.
Consider the distances between posts or columns, post centers in selecting length and width of pallet boxes.
Keep as close as possible to 48 inches in width and length but keep within legal highway limits.
Consider ceiling height of storage in selecting overall height of pallet box.